Permeable Pavements in Cold Climates: Lessons Learned from Practice and Research

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Porous pavements developed as early as the 1930s.

A sign at a park in Massachusetts. Image source: MAAPA
Full Depth Permeable Pavement X-Section

- Water infiltrates through permeable pavement surface and other layers
- Stored in gravel layer (~40% voids)
- Water infiltrates into soil or is collected by drain tile

Image: CAHILL Associates 2003
Project Scope

• Full depth permeable pavement:
  – Literature review
    • Structural design
    • Hydrologic design/performance
    • Water quality impact
    • Maintenance requirements
  – Cold climate case studies
  – Research needs
  – Software to determine feasibility of permeable pavement

• Does not include permeable friction course
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Image: www.epa.gov
Benefits of Permeable Pavement

- Volume Reduction
- Improved water quality
- Hydroplaning resistance
- Spray reduction
  - Increased visibility
- Smoother riding surface
- Noise reduction
- Less winter salt application

Photos: Barrett 2008
Permeable Pavement Types

- Porous Asphalt
- Pervious Concrete
- Permeable Pavers
- Permeable Articulated Concrete Blocks
Keys for Success

• Proper Construction
  – Mix design
  – Compaction
  – Void ratio
  – Curing

• Proper & regular maintenance
Summary of Hydraulic Performance

- Surface infiltration rates decrease but are not rate limiting
- Method needed to determine permeability of sub-base before design
- Geotextile fabrics can reduce/eliminate infiltration
- Infiltration rates are maintained through winter
Summary of Water Quality Impact

• Removes solids & solid-bound contaminants
• Mass load reduction often through infiltration
• Nitrification may occur (ammonium to nitrate), but total N removal is low
• Dissolved phosphorus removal is minimal

Photo http://switchboard.nrdc.org/
Summary of Maintenance

- Surface cleaning is effective but variable
- Particle removal (top ¼ inch) is major issue
- Pressure washing (45°) and/or vacuuming with regenerative air sweepers is most effective
- Brushes can push material farther into voids
- Clean multiple times per year
Summary of Maintenance

• Major cause of clogging is reduction of surface pavement void space:
  – Heavy loads
  – Particles
  – Lack of maintenance

• No standard to measure or evaluate clogging

Open voids

Partially clogged voids
Impact of Vacuuming

Permeable articulated concrete blocks/mats before (A) and after (B) cleaning with a Vac Head.

(Photo courtesy of University of Louisville and D. Buch, PaveDrain, LLC).
Porous Asphalt Paired Intersections - Robbinsdale

Constructed 2009-2010

Construction in September 2010 (Wenck 2014)
Paired Intersection Study

- Objective was to evaluate possible reductions in salt loads on porous asphalt pavements
- Also durability, maintenance, and water quality

Wenck 2014
Paired Intersection Study

- Two porous asphalt pavement intersection were constructed: one over a sand sub-base and the other over a clay sub-base.
- Designed to store the 2-yr storm
- Each porous asphalt section was approximately 150 feet long and 28 feet wide for a total area of about 4200 square feet.
- The porous asphalt sections were not salted during the winter.
- Conventional asphalt sections were salted.
Paired Intersection Study

Results

- Reservoir temperatures in both PP systems during winter was consistently warmer than the pavement temperature.
- Attributed to the air within the voids of the reservoir layer insulating the reservoir.
- Insulation minimizes winter freezing and keeps reservoir temperatures cooler in spring.
- Suggests winter infiltration into subgrade is possible.
Paired Intersection Study

Results

- Conventional pavement sites were slushier than the porous asphalt sites due to infiltration into PP

- Bare pavement on the porous test sections was comparable to that on conventional asphalt sections but had a lag of 2 to several hours
Paired Intersection Study

Slush gathering and refreezing on the traditional asphalt at Site 1 on January 17, 2010

Slush free porous asphalt on January 17, 2010
Paired Intersection Study

Site 1 Test Section looking south
Paired Intersection Study
Lessons Learned

• The unsalted, porous asphalt sections had a similar amount of bare pavement compared to salted, conventional asphalt sections.

• The porous pavement over sand subgrade was more effective for ice control compared to the porous pavement on clay subgrade.

• Porous asphalt sections have been durable without any special snow plow equipment or adjustments.
Paired Intersection Study

Lessons Learned

- Effective maintenance on the porous asphalt sections appears to be vacuuming (regenerative) twice per year and patching with traditional asphalt, as necessary.

- Porous asphalt intersections have potential as an ice-control management practice in certain situations.
Woodbridge Neighborhood-Shoreview, MN

Pervious Concrete, constructed in 2009.
Photo courtesy of M. Maloney
Woodbridge Neighborhood

Initially:

• 38 ac, fully developed
• 9000 yd$^2$ of asphalt
• Storm drainage concerns

Needed to:

• Replace road, upgrade utility, improve stormwater management
• Total cost = $15M
Woodbridge Neighborhood

Why PC?
• Free draining soils
• Advances in mix designs and placement techniques
• Same cost as conventional asphalt with storm drains
Woodbridge Neighborhood - Construction

- 18” crushed rock reservoir
- Tri-roller screed for consolidation
- Curing fabric used instead of poly sheeting placed within 1 minute (7 day duration)
- Mix Design: 125 PCF, 21% air voids (+/- 3%)
- 7” of pervious concrete
- 1.5” Railroad ballast, 18-30” thick
- $86.30 per SY
- Saw cut joints 24-48 hours after pour

Curing of Pervious Concrete.  
Photo courtesy of M. Maloney
Woodbridge Neighborhood - Maintenance

• Regenerative air sweeper (no brushes); ~ every 6 weeks
• No salt or sand application
• Plowed by one-ton pickup w/ regular plow
• Clogging occurs mostly in top ¼” of pavement
• Maintenance has maintained infiltration rates of 300-500 in/hr in most areas
Lessons Learned

- Construction & curing very important
- Saturated curing blankets have been successful
- Saw cut joints have been successful
- Snow plowed with regular plow
- Maintenance is effective
• After 5 years, 20% of traverse joints were spalled & 15% surface raveled
• Deicing salt section most raveled
• Hydraulic conductivity is decreasing but still at functional level
• Sound adsorption is decreasing
• Including maintenance costs and anticipated surface grinding, pervious concrete is more cost effective than alternatives
The Denver (UDFCD) Experience

Denver, Colorado.       Photo: PlaneandJane.com
Denver Safeway Parking Lot

- Pervious Concrete
- Installed in 2004
- No info on mix design
- Surface erosion
Denver Waste Management Building

• Cores revealed proper construction (17% voids, proper PSD, asphalt content, etc.)

• More than half of other PA sites have infiltration < 20 in/hr

• UDFCD does not recommend use of PA
Overall Conclusions

• Permeable pavements can result in less winter salt application

• Permeable pavements can reduce runoff volume and improve water quality (with other benefits)

• Permeable pavements are more expensive to construct

• Construction & maintenance are critical to success
Overall Conclusions (Cont’d)

- Maintenance: pressure washing and/or vacuuming
- Permeable pavements can withstand harsh winters
- Permeable pavements can maintain infiltration rates throughout the winter
- Advances are being made continuously
Thank you for your attention!

Questions?

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Research Needs

- Structural/Construction: long-term performance, aggregate grading, geotextiles, compaction energy, in-situ tests, life-cycle cost analysis...
- Hydraulic/WQ: mix design as pollution source, hydraulics w/ heavy loads, raised drain tile, long-term WQ, N/P fate..
- Maintenance: quantify clogging, cleaning methods, frequency, optimal pavement design...

http://www.vaasphalt.org